ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Distributed Systems Group | Institute for Pervasive Computing

Interactive 3D Displays

Shaban Shabani
sshabani@student.ethz.ch

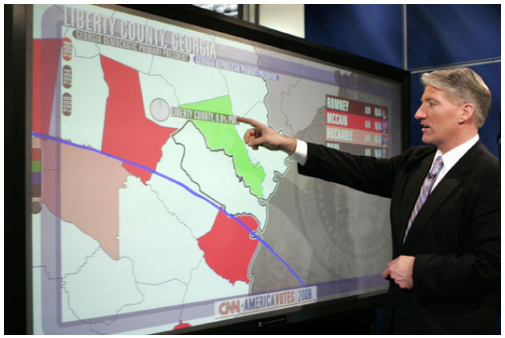
Interaction with displays

- **Old technique, still in use**
  - Several drawbacks
  - High adaption
- **Isn't this already perfect?**
- **Why do we need more?**

Touch screens

- **Displays show dynamic data**
  - Heavy content
  - Requires efficient interaction by the user

- **Touch-screens**
  - Direct interaction on the screen
  - Controlling content with great enthusiasm
  - Multi-touch feature
  - Wide application



- **Drawbacks**
  - Single screen
  - Limited to the physical extent of the display

Beyond touch screens

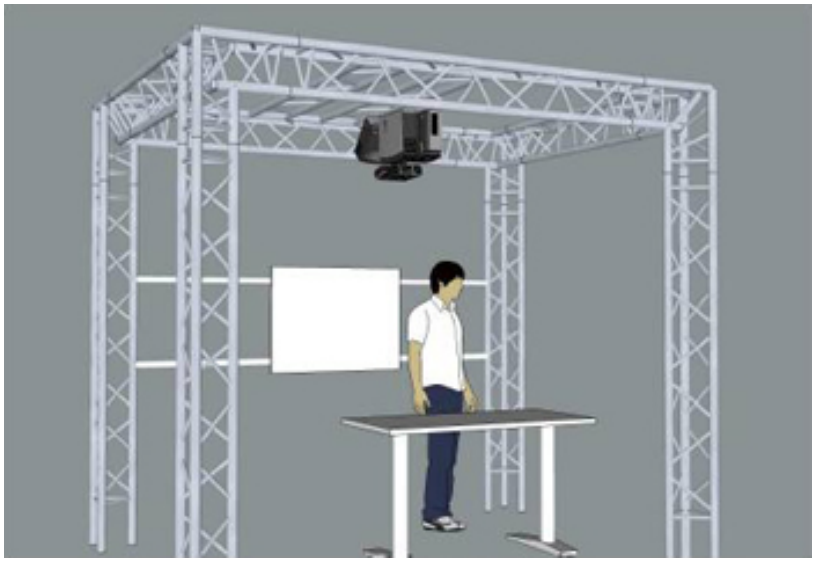
- **Move interactivity off the display and into environment**
- ***"Office of the future"***

"*The office of the future: A unified approach to image-based modeling and spatially immersive displays*"
R. Raskar et al.

LightSpace – "smart room"

"Once, computers were the size of entire room.
Today, the entire room is turned into a computer."

- **Small room installation**
  - Use of depth cameras and projectors
  - Interactions on, above and between surfaces
- **Merge of techniques**
  - Surface computing
  - Augmented reality

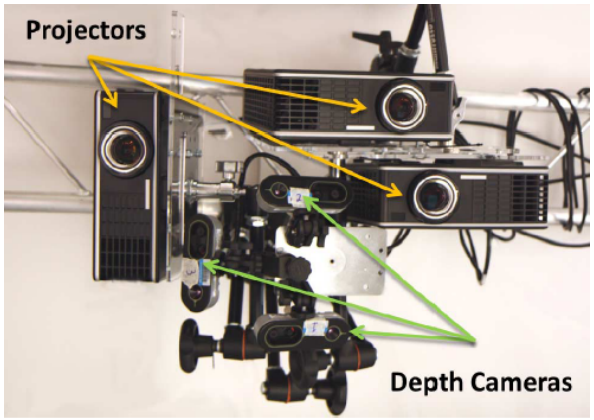


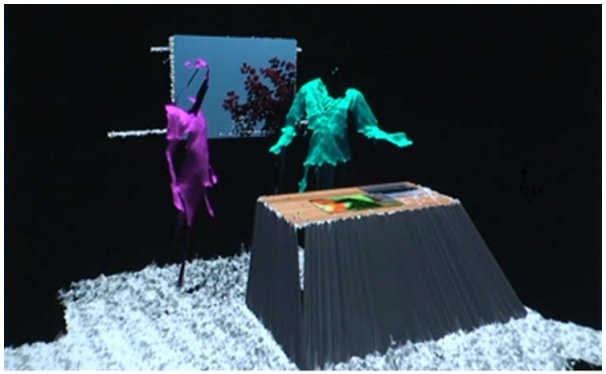
LightSpace configuration

"*Combining multiple depth cameras and projectors for interactions on, above and between surfaces*"
A.Wilson and H.Benko

Overview

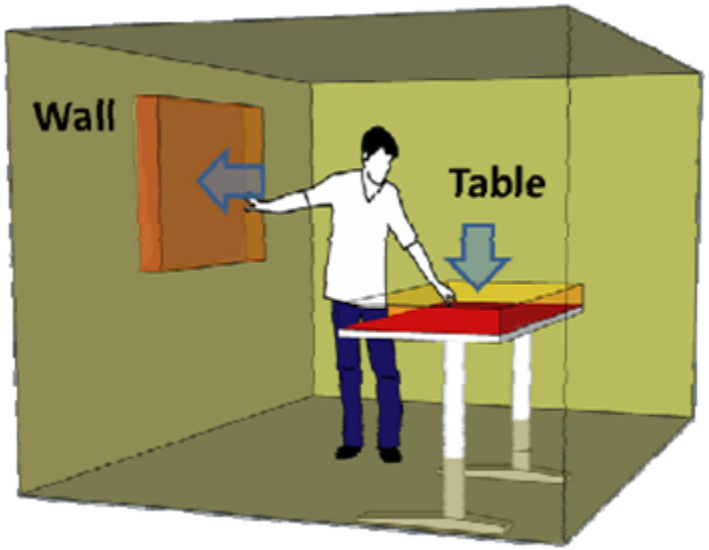
- **Depth-sensing cameras**
  - Calculate depth of the objects in the scene
  - Track user's position and interactions
  - Capture in real-time 3D mesh model of the sensed space
- **Projectors**
  - Virtual objects projected in the real space on top of real objects





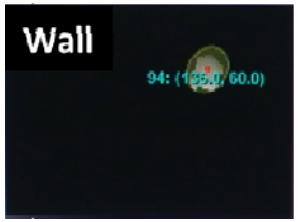
Interactive displays

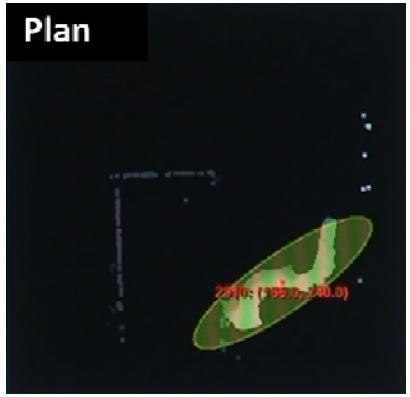
- **Surface everywhere**
  - Room physical surfaces should be interactive “displays”
  - e.g. interactive wall and interactive table
- **The room is the computer**
  - Space between surfaces is active as well
- **Body as display**
  - Graphics projected on user’s body

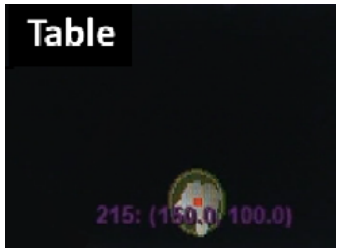


Operation

- **Depth cameras provide 3D mesh model**
- **Implementation of interactions**
  - Avoids calculations directly on 3D mesh model
  - Transform data to an image generated by a “virtual camera”
  - 3 orthographic virtual cameras “*wall*”, “*table*” and “*plan*”

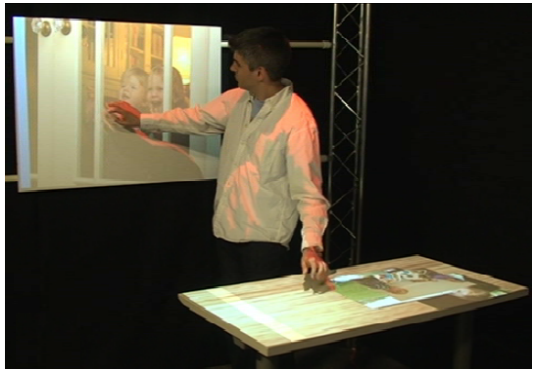


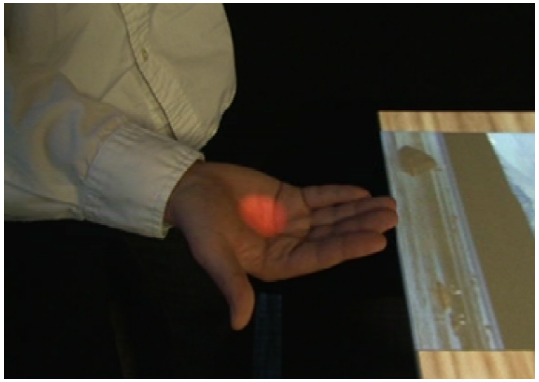




Interactions

- **Interactive surface**
  - Manipulate with projected objects in the surfaces
- **Through-body transitions between surfaces**
  - Move objects between surfaces
- **“Picking up” objects**
  - Drag an object and pick it up with hand



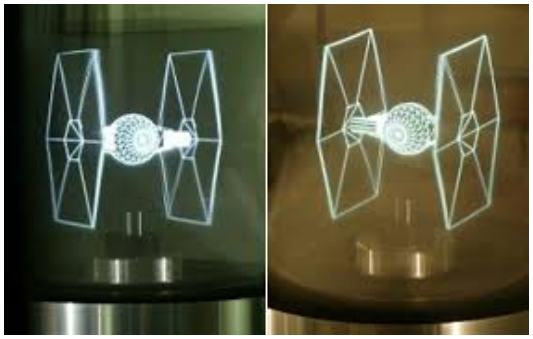


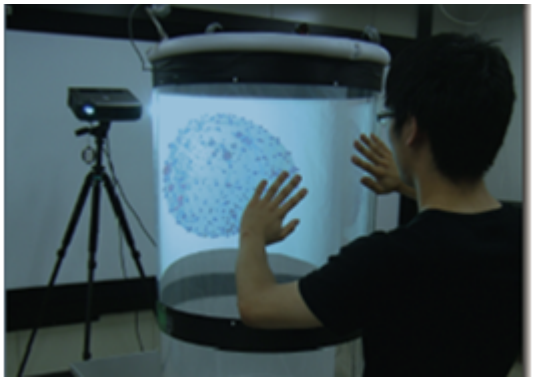
Video

http://www.youtube.com/watch?v=gc_Xj7Z8aLU

More than surfaces

- The world is 3D
- More DOF for tasks with such demands
- More visual information
- Exciting and more realistic than 2D



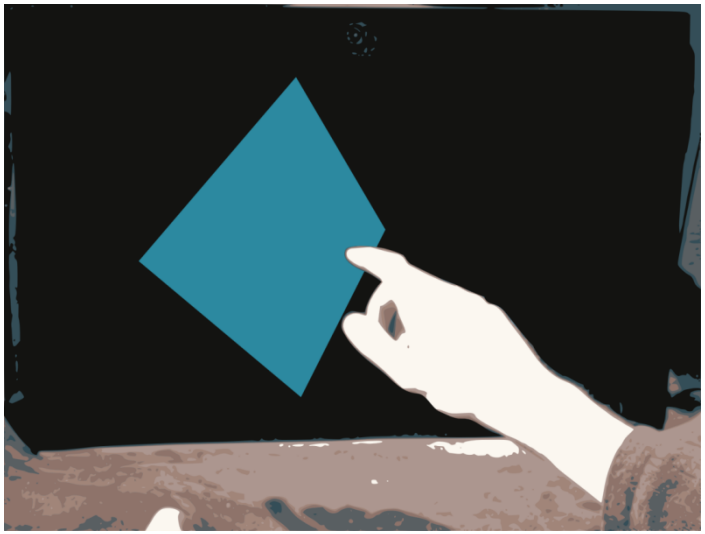


3D displays

- **Require the wearing of special glasses**
- **Non interactive**
- **Interactive ones mainly require additional hardware**
  - Data gloves
  - Head-mounted display
  - Gamming controllers

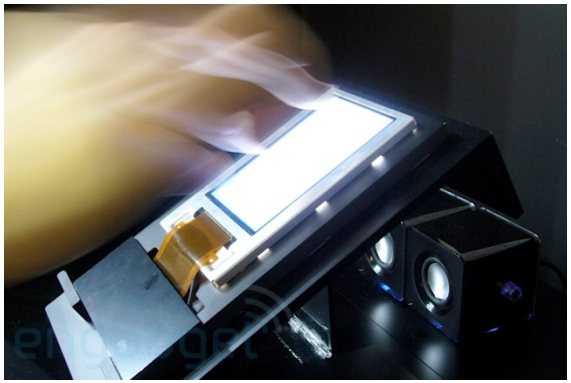
BiDi Screen

- **Bidirectional screen**
- **Turn an LCD in a thin display to support:**
  - Image capture and display
  - On-screen 2D multi-touch
  - Off-screen 3D interaction
- **No need for glasses or HMD**



"BiDi Screen: A Thin, Depth-Sensing LCD for 3D Interaction using Light Fields"
M.Hirsch et al.

BiDi - Inspiration

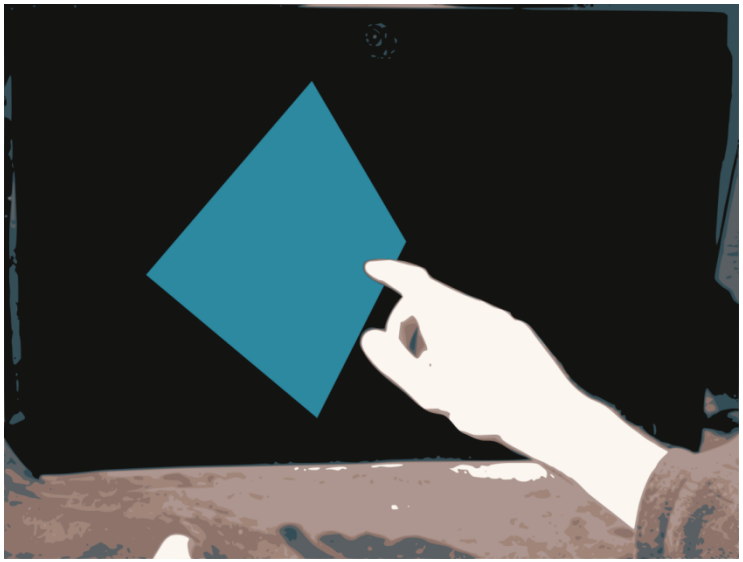


Light sensitive display

Depth camera

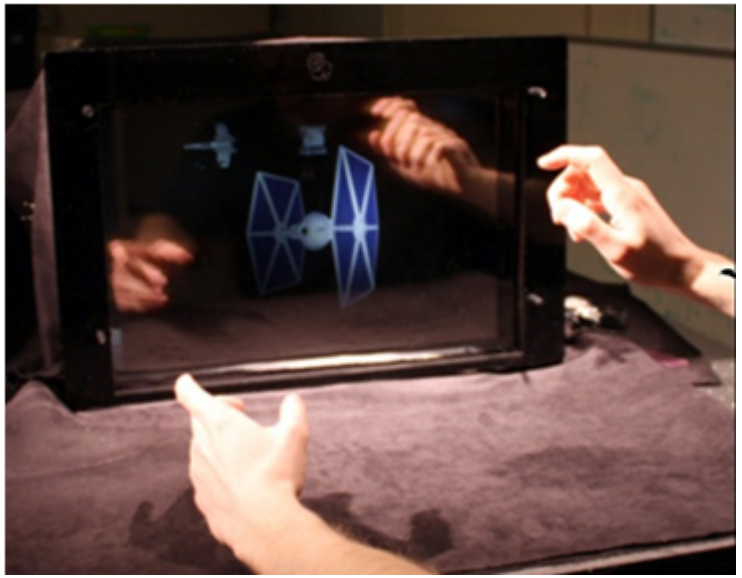
Multi-touch display

- **Combine in a single device**



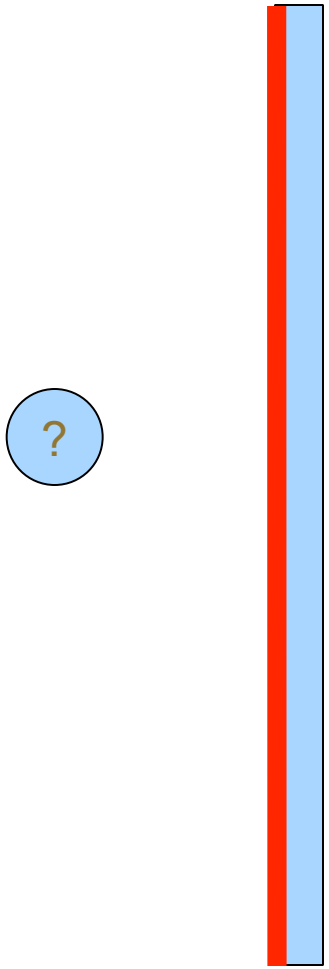
BiDi - Challenges

- **Build a thin portable device**
- **Enable multi-touch and 3D gesture interaction**
- **Collocated image capture and display**



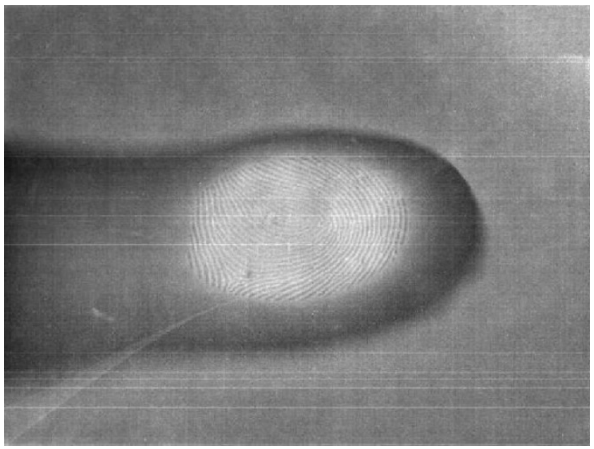
- **How to capture depth from an LCD?**

Background - Traditional touch?



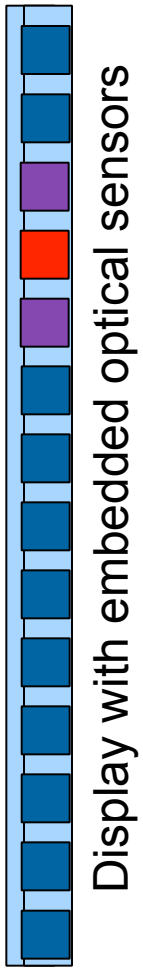
- **Resistive and capacitive multi-touch displays**
  - Only sense the surface of the display

Motivation – Optical multi-touch device



- **LCDs from Sharp and Planar**
- **Optical sensors**
  - Capture sharp image of objects when in contact with the surface of the screen
  - As objects move away from the screen, the images are blurred

Motivation – Optical multi-touch device



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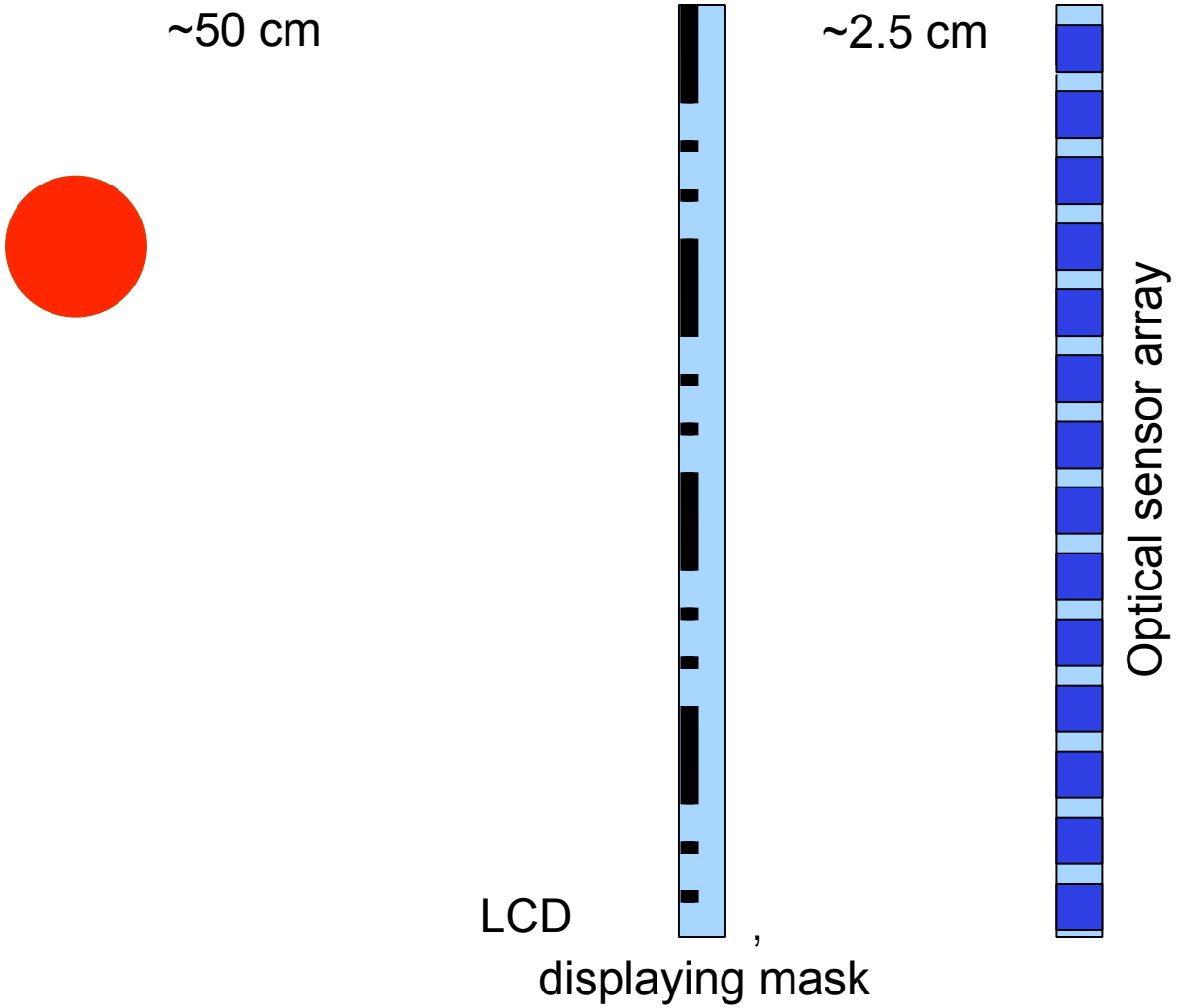
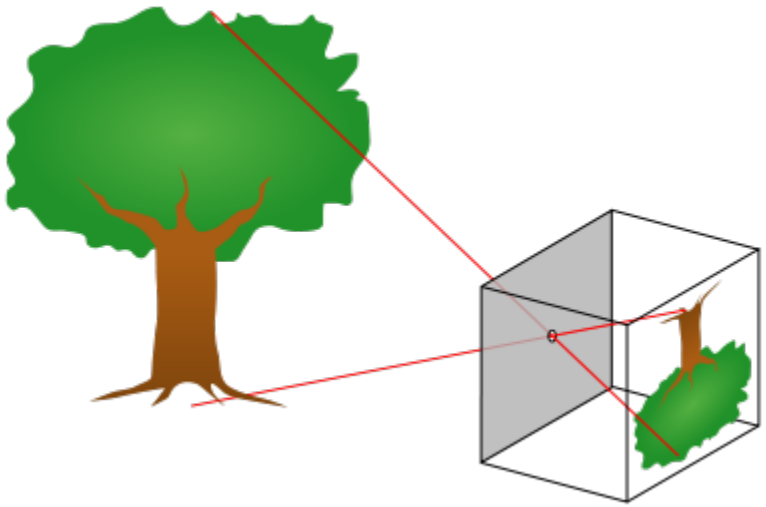
Design vision



- **Separate the optical sensor by a small distance from the LCD**
- **Collocated display and capture**

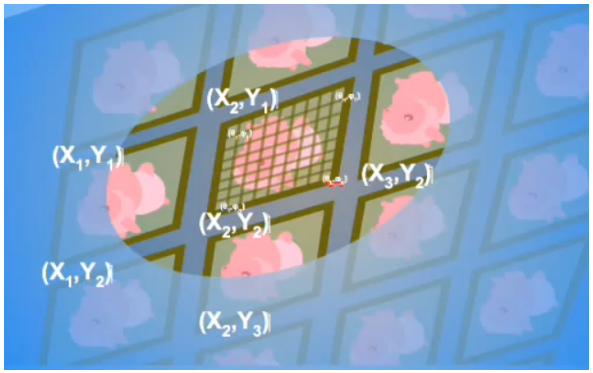
Pinhole camera

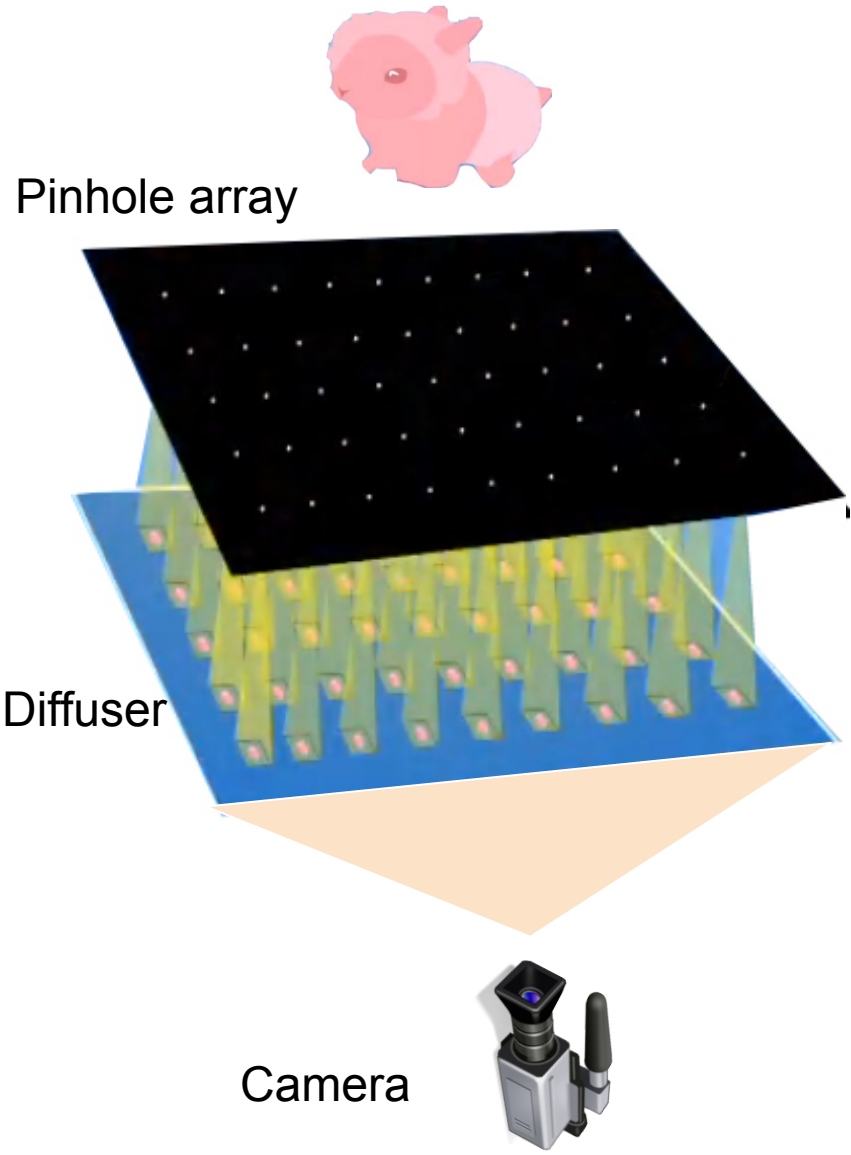
- **Simple camera without lens and small aperture**
- **Light passes through the single point**
- **Projects inverted image on the opposite side of the box**



Design overview

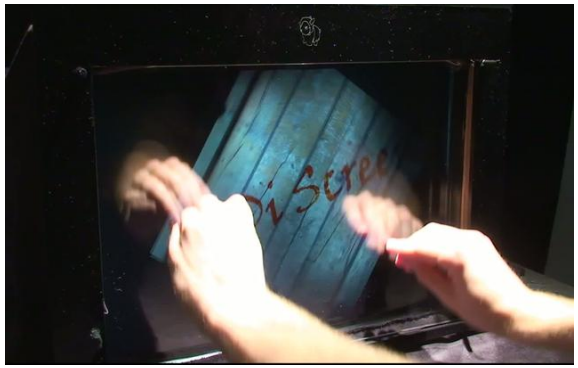
- **Display a pinhole of arrays**
  - Creates tiny images on the sensor array each with different angle view
- **Camera captures images**
- **Analyze patterns of the images**
  - Decode depth

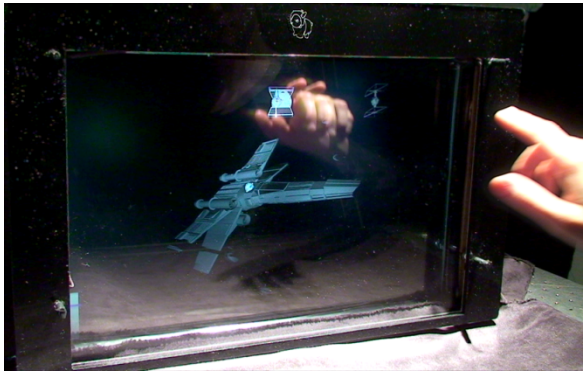




Interactions

- **On-screen multi-touch interactions on objects**
  - Resize
  - Rotate
- **Off-screen 3D gestures**
  - Move objects in 4 directions
  - Zoom in/out objects in 2 directions





Video

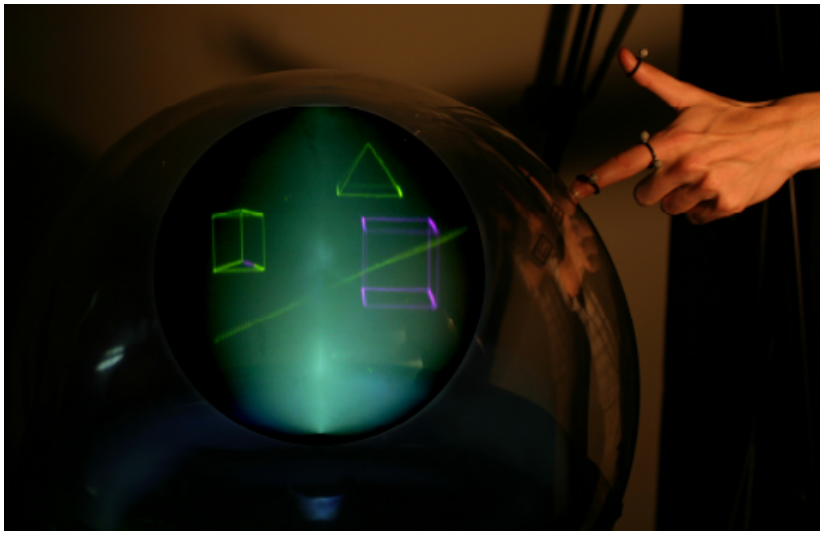
http://www.youtube.com/watch?v=kXuxK6IeQfo

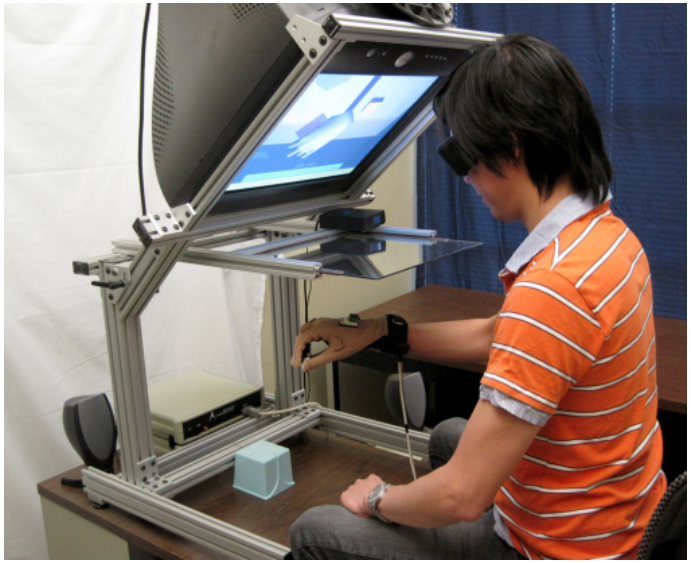
Summary

- **Benefits**
  - A modified LCD that supports multi-touch and 3D gestures
  - No special hardware
  - Real-time interaction
- **Limitations**
  - Size
  - Lighting
    - Requires external lighting
    - Not functional in case of absence of illumination

In-volume 3D interaction

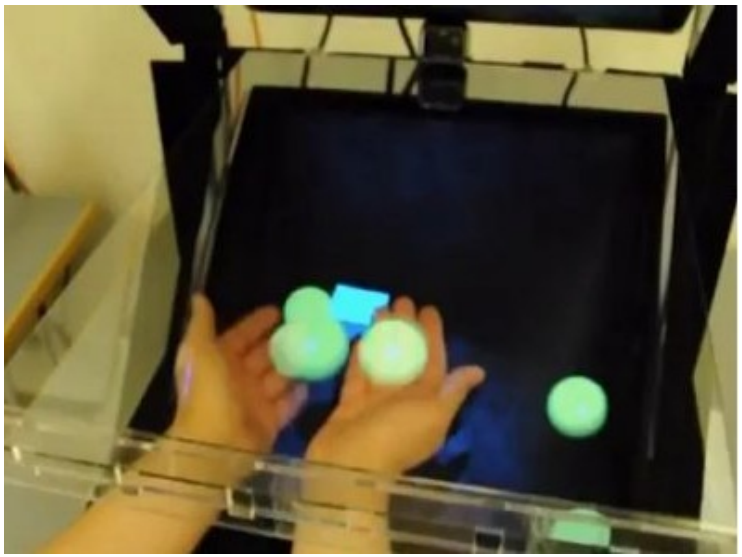
- **Direct interaction on the 3D content not possible**
  - Behind glass
  - Some require special glasses and data gloves





HoloDesk

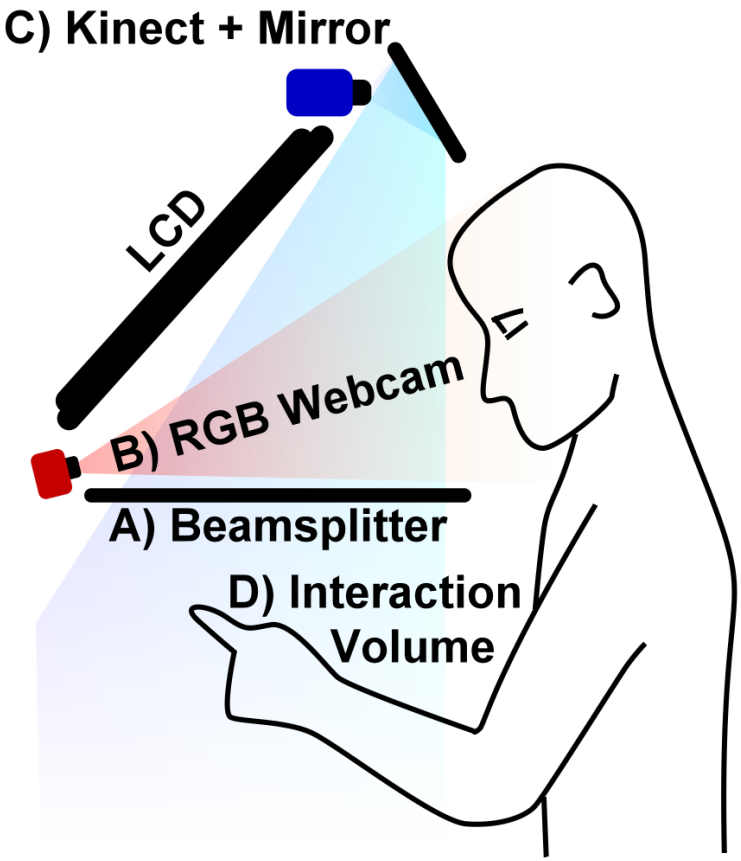
- **An interactive Augmented Reality system**
- **Interact with 3D virtual objects**
  - ‘Inside’ the display
  - No need for body-worn hardware
- **Physically realistic interactions**
- **‘Walk-up-and-use’**
  - No user instrumentation



“HoloDesk: Direct 3D Interactions with a Situated See-Through Display”
O.Hilliges et al.

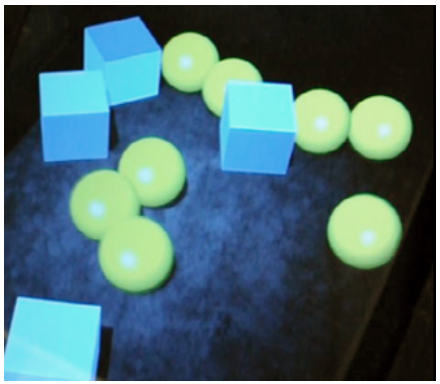
Design overview

- **Interaction volume**
  - Seen through beam splitter
- **Optical see through mirror (Beam splitter)**
  - Reflects light to the user from the LCD
  - Forms a virtual image on interaction volume
- **RGB Webcam**
  - Tracks user's head 6DOF
- **Kinect + mirror**
  - Mirror fold the Kinect's optic
  - Sense the interaction volume



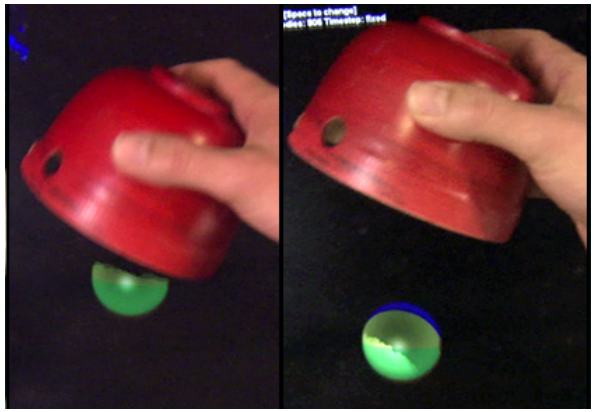
Operation

- **Correctly virtual graphics**
  - Tracking and estimating 3D position of head
  - Continuously updating the rendering
- **Kinect**
  - Real-time depth data
  - Occlusion
  - Inter-shadowing



Virtual scene

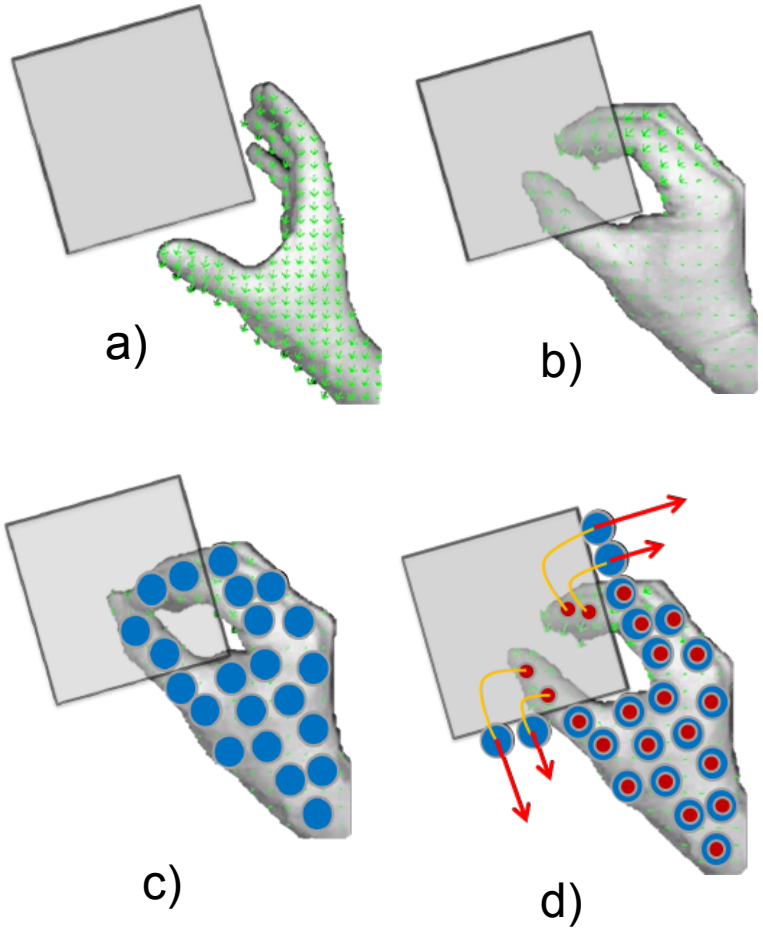
Occlusion



Inter-shadowing

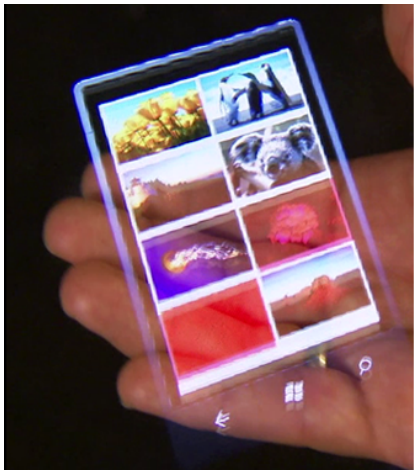
Implementation

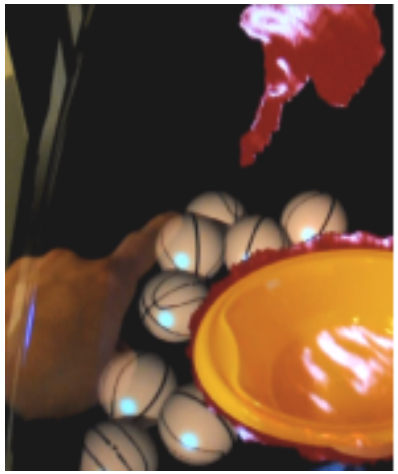
- **Simulating human grasping**
  - Accurately model collision and friction forces exerted onto virtual objects
  - Kinect depth data approximated by small spherical rigid bodies
  - Approximate the shape, motion and deformation of 3D physical objects
  - Model interpenetration of objects



Applications

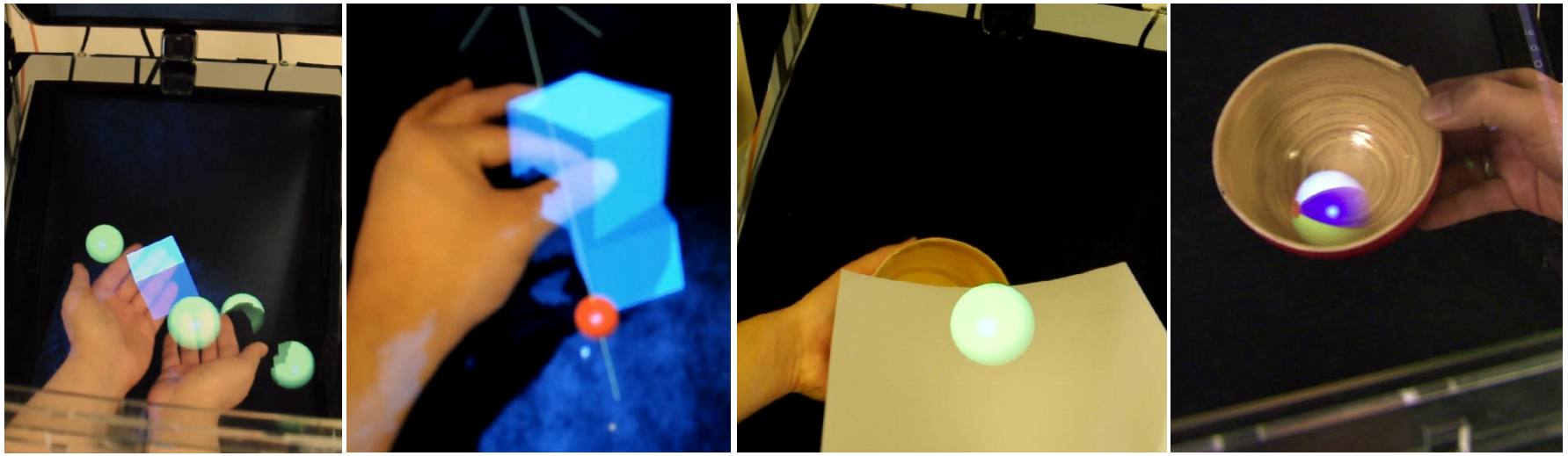
- **Mix of real and virtual content**
- **Gaming**
- **Virtual prototype**
  - Smartphone
  - Touch-enabled
- **Telepresence**
  - Users share single virtual 3D scene
  - Interactions relayed to a remote unit





Interactions

- **Physics-enabled interactions**
  - Interact with virtual in realistic way
- **Rich free interactions**
  - Juggling, grasping



Video

http://www.youtube.com/watch?v=JHL5tJ9ja_w

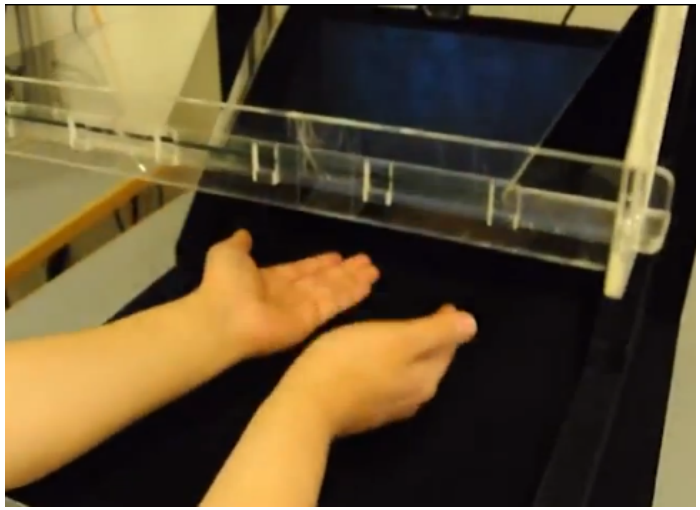
Summary

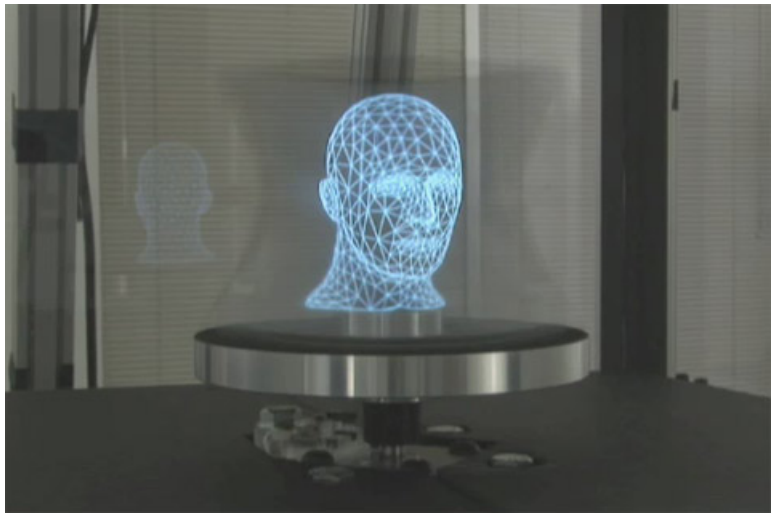
- **Benefits**
  - Novel system which supports full 3D interactions
  - No user instrumentation
  - No head-worn sensors
  - Direct interactions with 3D objects
  - Rich physically inspired interactions
  - Various applications

- **Limitations**
  - Does not provide full simulation of object motion in the interaction volume
  - Failures in case of occlusion of physical objects
  - Finger grasping requires visible fingertips

Towards 360-degree viewing displays

- **Previous displays have user restrictions on interacting with volume**
  - Limited viewpoint
  - Glass separates the physical display from user





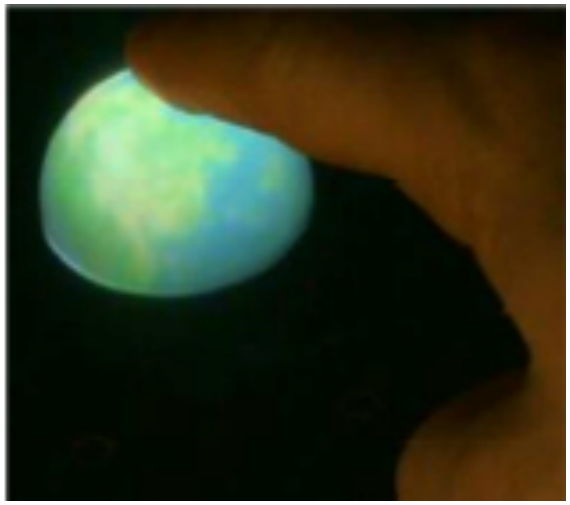
Video

http://www.youtube.com/watch?v=YKCUGQ-uo8c

"Rendering for an Interactive 360° Light Field Display"
A.Jones et al.

Vermeer

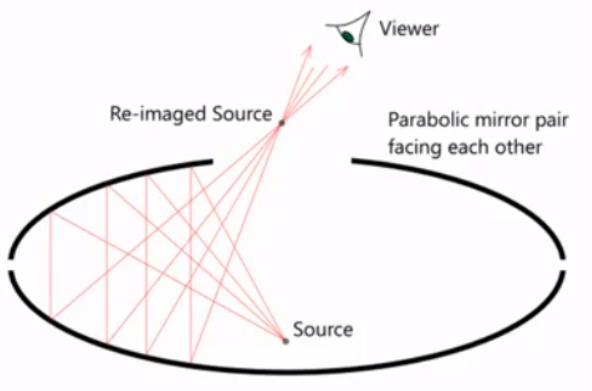
- **A new enabling technology for in-volume interaction**
- **360°viewable 3D display**
  - Viewpoint corrected
  - No need for eyewear
  - No user instrumentation
- **Directly touch and interact with 3D objects inside the display volume**



"Vermeer: Direct interaction with a 360-degree viewable 3D display"
A.Batler et al

Motivation

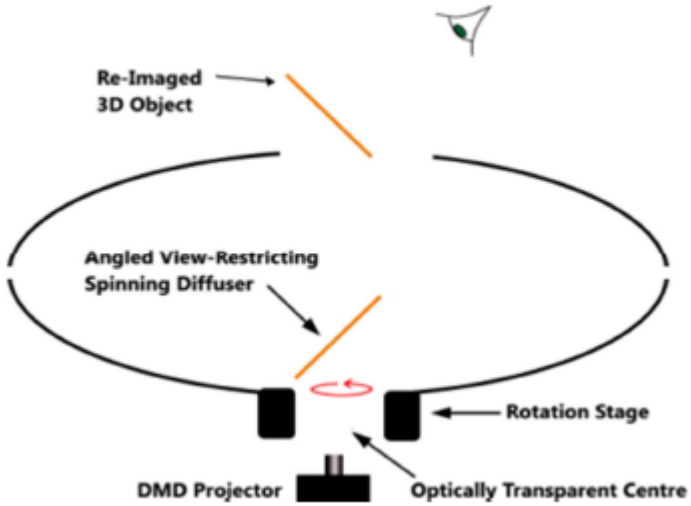
- **Optical illusion using 2 parabolic mirrors**
  - Object placed at the bottom of the mirror *reimaged* as it was real, above the unit
  - Provides 360°view
  - Allows free interaction without encumbering the projection



Video - Parabolic mirrors

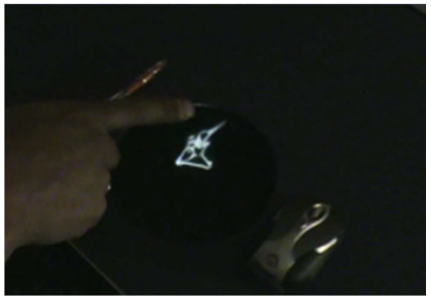
Design overview

- **An extended 360 viewable 3D display**
  - Projection
  - Imaging from below
- **View restrictive spinning diffuser**
  - Provides the narrow viewing angle
  - Different views to multiple users
- **High speed DMD projector**
  - Displays multiple viewpoints of the 3D scene at high rates
  - 2880 images/second
    192 different views per rotation



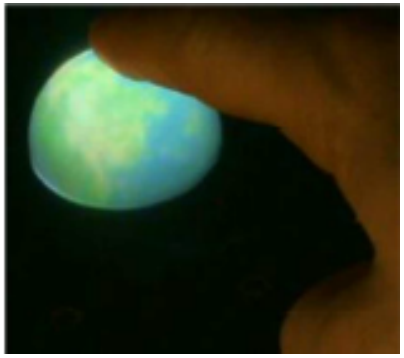
Sensing interactions using Kinect

- **Kinect depth camera positioned above**
  - User places finger inside the volume
  - Contour of the hand detected and *fingertips* tracked
  - Animate 3D scene
- **Physics simulation (nVidia PhysX)**
  - More realistic interaction
  - Control visual objects with real-world concepts: forces, collisions and frictions



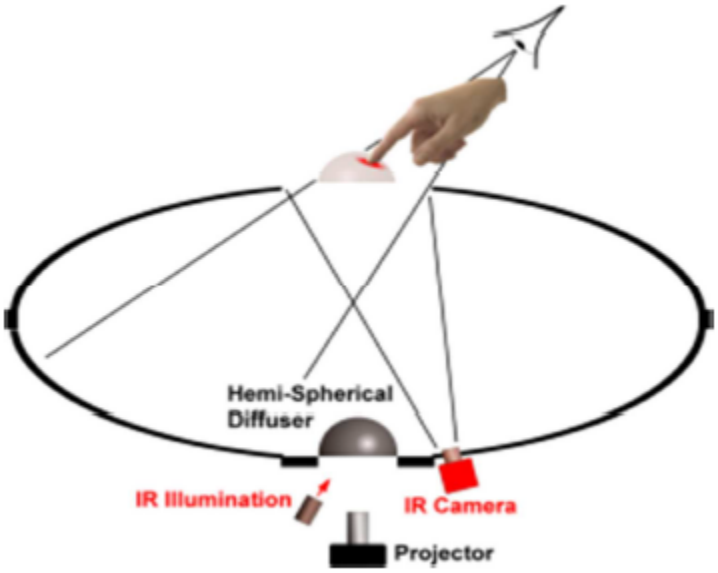
Sensing interactions using infrared

- **Enabling interactions with Kinect**
  - Increases complexity
  - Suffers from bulk and occlusion



- **Infrared reimaging**
  - Parabolic mirror reimage light in the near IR-range
  - An object reimaged using IR, *floats* in the display area
  - Fingertips intersecting with objects detected with an IR camera

- **Sense intersections between physical objects above and IR illuminated inside**
  - e.g. spinning sphere
  - Distinguish finger touching object from others



Video

http://www.youtube.com/watch?v=lW7k-6FUxoo

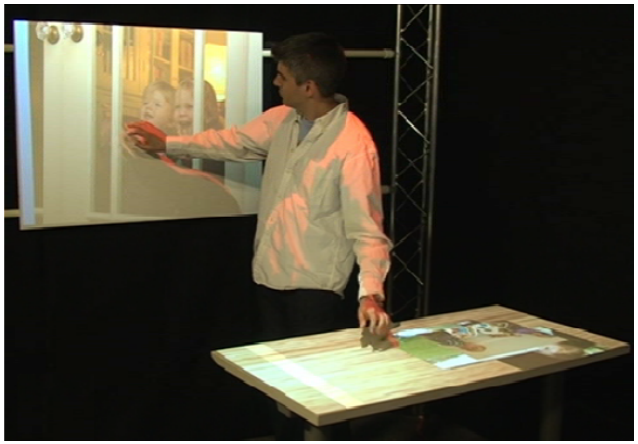
Summary

- **Benefits:**
  - Novel technique in interacting with 360°viewable 3D displays
  - Supports multiple users
  - No need for glasses and instrumentation

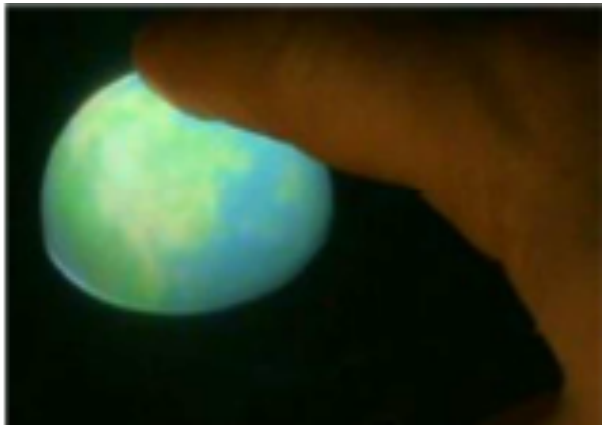
- **Limitations**
  - Small dimensions of the viewable volume
  - View constraints when viewpoint too high or too low
  - Distortion of the displayed image
  - Limited rendering fidelity

Summary

Interactions on 2D surfaces

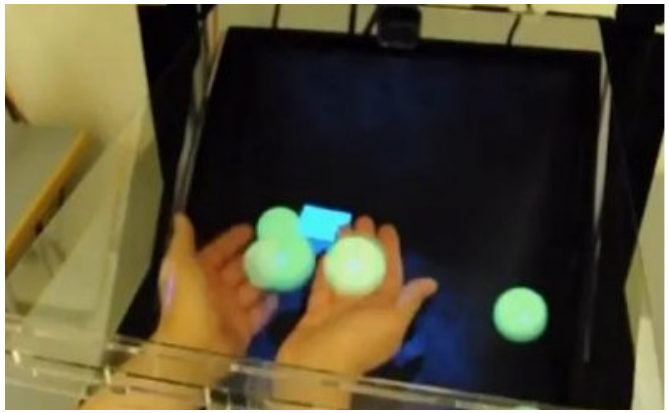


360° viewable display



3D off-screen interactions

In-volume interactions



Summary

	LIghtSpace	*BiDi*	*HoloDesk*	*Vermeer*
3D interaction	✗	✓	✓	✓
No need for glasses, gloves, HMD	✓	✓	✓	✓
Rich free interactions	✓	✗	✓	✓
In-Volume interaction	✗	✗	✓	✓
Full 360-degree view display	✗	✗	✗	✓